Executive Summary

1. Introduction

This report has been prepared to provide the City of Lincoln with a guide for short-term and long-term improvements to the infrastructure for the Lincoln Water System. The recommended improvements plan presented herein will serve as a basis for the design, construction, and financing of facilities to meet the City's anticipated population growth and commercial development. The report has been extensively coordinated with the Lincoln-Lancaster County Planning Department and the current Comprehensive Plan; therefore we are confident that the recommended improvements will provide an adequate and dependable supply of water to existing and future customers. The Study Area for this investigation and report is shown on Figure ES-1.

2. Population

Historical population data for the City of Lincoln was obtained from the U.S. Census Bureau. The Lincoln-Lancaster County Planning Department provided aggregate population projections for the City of Lincoln for 5-year intervals from year 2000 to year 2050. Historical and projected population for the City of Lincoln, as used in this study are summarized in Table ES-1.

Table ES-1
City of Lincoln Population
(Historical and Projected)

Year	Population	Annual Growth	
		Persons	%
1940	81,984(1)	--	--
1950	98,884(1)	1,690	1.89
1960	128,521(1)	2,964	2.66
1970	149,518(1)	2,100	1.52
1980	171,932(1)	2,241	1.41
1990	191,972(1)	2,004	1.11
2000	225,581(1)	3,361	1.63
2010	261,796(2)	3,622	1.50
2025	327,306(2)	4,367	1.50
2050	474,903(2)	5,903	1.50

(1)U.S. Census Bureau.
(2)Projections by Lincoln-Lancaster County Planning Department dated March 27, 2001 based on growth rate of 1.5 percent per year as selected by Comprehensive Plan Committee on March 23, 2001.

Figure ES-1 Study Area

3. Water Requirements

Projected water demand requirements are summarized in Table ES-2. The projections are based on reduced per capita usage rates which have resulted from conservation efforts over the last 15 to 20 years.

Table ES-2
Projected Water Requirements (Total System)

	Design Year			
	Base	2010	2025	2050
Population	225,581	261,769	327,306	474,903
Residential Metered Sales (mgd)	21.0	24.3	30.4	44.2
Total Metered Sales (mgd)	33.8	39.3	49.1	71.2
Unaccounted-for Water (mgd)	2.3	2.6	3.6	5.3
Average Day Demand (mgd)	36.1	41.9	52.4	76.0
Maximum Day Demand (mgd)	97	113	141	205
Maximum Hour Demand (mgd)	159	184	230	334
Summer Seasonal Yield Required	56	65	81	118

4. Water Supply

The capacity of the water supply system is governed by two separate criteria. First, the source of supply must be capable of yielding the volume of water needed and second, the capacity of the facilities must be adequate to deliver maximum day demands.

Definitions

Sustainable Yield: Rate of withdrawal which can be diverted indefinitely at a given river flow rate.

Summer Seasonal Yield: Average rate of withdrawal which can be diverted over a period of 120 days (May 15 – September 15).

14-Day Maximum Yield: Maximum rate with can be diverted over a period of 14-days at a given river flow rate.

Maximum Day Capacity: Maximum capacity which can be delivered by the supply facilities over a 24-hour period.

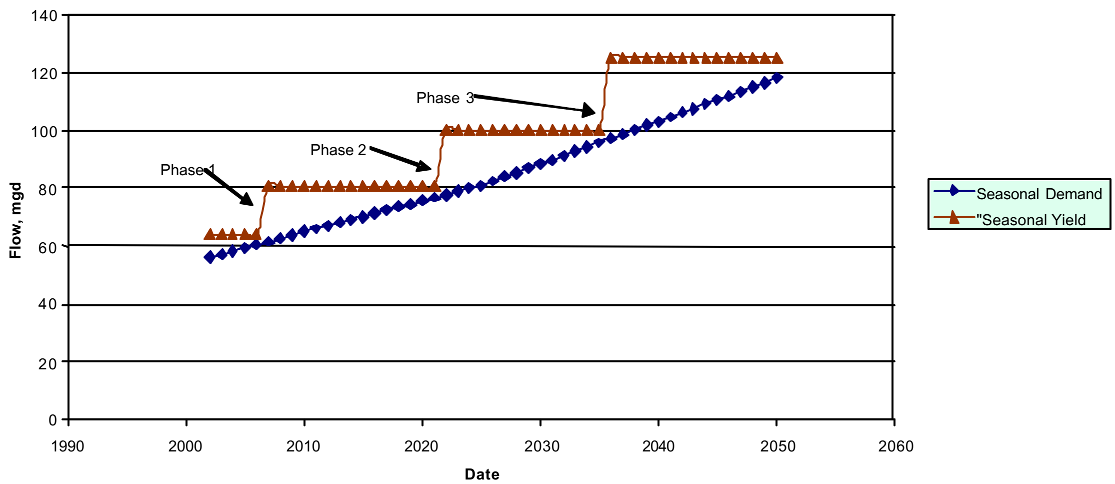
Firm Capacity: Capacity of the supply facilities with the largest component out of service. This condition does not consider availability of water.

4.1 Source of Supply

Three phases of expansion are recommended to meet seasonal demands for the assumed worst-case drought conditions. Phase 1 will increase the summer seasonal yield to approximately 81 mgd and should be planned for approximately year 2007 to ensure adequate supplies are available as shown on Figure ES-2. Phase 2 of the expansion is recommended to expand the summer seasonal yield to approximately 100 mgd and should occur approximately by Year 2020. The third phase of expansion should occur by Year 2031 and should expand the summer seasonal yield to 125 mgd.

Figure ES-2

Seasonal Demand vs. Summer Seasonal Yield

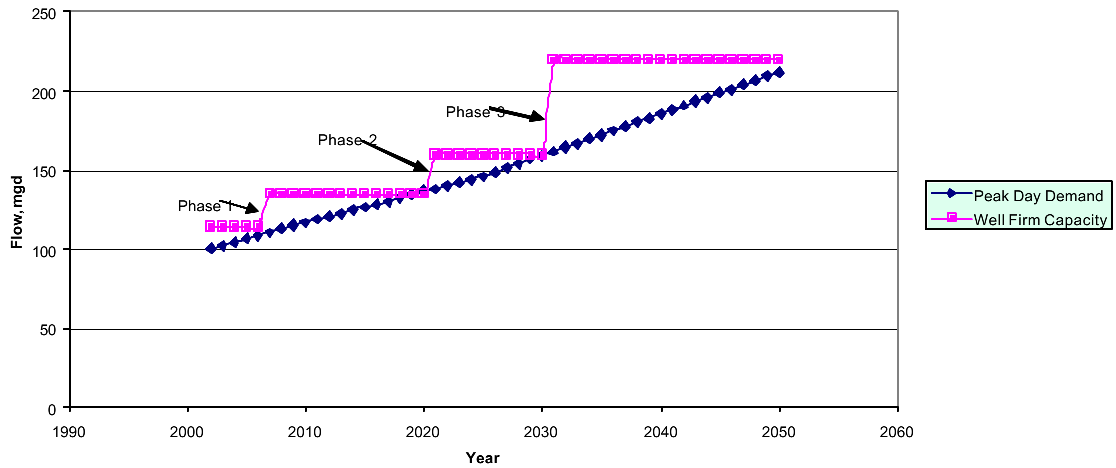


4.2 Hydraulic Capacity

The supply infrastructure's ability to meet maximum day demands is controlled by individual raw water transmission system facilities as well as the capacity of the transmission pipelines to the water treatment plants.

The existing supply infrastructure capacity is calculated to be approximately 114 mgd. Therefore, expansion of the supply infrastructure to meet projected maximum day demands will be required prior to Year 2010. Expansion of the firm capacity to approximately 131 mgd by Year 2007 is recommended for Phase 1 as shown in Figure ES-3. Phase 2 includes expansion of the firm capacity to approximately 160 mgd by Year 2020. By Year 2031, the firm capacity should be expanded to 220 mgd.

Figure ES-3
Maximum Day Demand vs. Supply Capacity



4.3 Phasing of Supply Improvements

4.3.1 Phase 1

As demands grow and additional raw water supply is needed, the primary components of Phase 1 will be the construction of new supply facilities and rehabilitation/replacement of others to increase the firm capacity to 131 mgd. The total opinion of probable cost for this phase is $9,118,000.

4.3.2 Phase 2

Phase 2 will also include construction of new supply facilities and additional upgrades to increase the firm capacity to 160 mgd. The opinion of probable cost for these improvements is $10,049,000.

4.3.3 Phase 3

The third phase of expansion of the supply system will develop the remainder of the supply facilities to ultimate capacity and rehabilitate/replace others. This will increase the summer seasonal yield to 125 mgd and the firm capacity to 220 mgd. This expansion will require construction of additional pipelines to the water treatment plant. The opinion of probable cost for these improvements is $29,000,000.

Proposed water supply improvements are summarized in Table ES-3.

Table ES-3 Proposed Water Supply Improvements							
Phase	Year	Elements	Cost $	Additional Firm Capacity (mgd)	Total Firm Capacity (mgd)	Additional Summer Seasonal Yield (mgd)	Total Summer Seasonal Yield (mgd)
1	2007	Supply Improvements and Rehabilitation/ Replacement	9,118,000	21	135	16	81
2	2020	Supply Improvements and Facility Upgrades	10,049,000	25	160	19	100
3	2031	Additional Supply System and Rehabilitation/ Replacements	29,000,000	60	220	25	125

5. Water Treatment

5.1 Regulatory Evaluation of Existing Treatment Facilities

Drinking water regulations dictate the treatment process to be used by the LWS so current and future regulations were evaluated to determine the impact on water treatment operations. The East and West Plants are in compliance with all existing drinking water regulations and should be in compliance with pending and future regulations. The following sections highlight some of the key requirements that LWS will be faced with.

5.1.1 Disinfectants/Disinfection Byproducts

The Stage 1 and Stage 2 Disinfectants/Disinfection Byproducts Rule (DBPR) regulates maximum disinfectant residuals and requires reduction of disinfection byproduct precursors and the reduction of disinfection byproducts. The Trihalomethane (THM) and Haloacetic Acid (HAA) requirements, that went into effect in January 2002, require compliance with a system wide running annual average (RAA) of 80 and 60 ppb for THMs and HAAs, respectively, based on quarterly samples. The future requirements, Stage 2 DBPR, will change the requirement from a system wide average to compliance with a local running annual average (LRAA) at selected sites within the distribution system. Based on the historical data and the fact that LWS uses chloramines as a secondary disinfectant, LWS should be able to comply with the current and future THM/HAA requirements.

5.1.2 Cryptosporidium Inactivation/Removal

The Interim Enhanced Surface Water Treatment Rule (IESWTR) requires a 2-log (99 percent) inactivation/removal of *Cryptosporidium*. However, if the utility meets the 0.3 NTU 95 percent of the time in combined filter effluent requirement, they will be credited with 2-log removal of *Cryptosporidium* and not be required to show additional removal/inactivation.

With filter-to-waste capability, the LWS should be able to meet the turbidity requirements, and therefore meet the *Cryptosporidium* requirements.

The Long-term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) will require monitoring the source water for *Cryptosporidium* and then inactivation/removal based on the monitoring data and classification within a "bin" (Table ES-4). The baseline inactivation/removal of *Cryptosporidium* will be increased to 3-log (99.9 percent) and will increase with increasing occurrences of *Cryptosporidium* in the raw water.

Table ES-4
Bin Requirements

Average *Cryptosporidium* Concentration oocysts/L	Additional treatment requirements[1]
Crypto < 0.075/L	No action
0.075/L ≤ *Crypto* < 1.0/L	1-log treatment (0.5 + 0.5 log or 1.0 log or greater from toolbox)
1.0/L ≤ *Crypto* < 3.0/L	2.0 log treatment (with at least 1 log inactivation from UV, ozone, chlorine dioxide, membranes, bag filters, or river bank filtration)
3.0/L ≤ *Crypto*	2.5 log treatment (with at least 1 log inactivation - e.g. UV, Ozone, Chlorine Dioxide, membranes, bag filters, or river bank filtration)

(1) Log treatments indicated are in addition to the 3-log removal requirement/credit for *Cryptosporidium* in a conventional plant, as indicated in the Stage 2 Agreement in Principle. Direct filtration plants may be required to achieve an additional 1 log removal/inactivation for compliance.

If a plant is a conventional plant and they meet the 0.3 NTU combined filter effluent turbidity requirements, their removal credit will be increased from 2-log to 3-log. However, it is not clear if a direct filtration plant will be given the 3-log credit for meeting the turbidity requirement or if they will only still receive the 2-log credit. Depending upon the bin classification and the baseline removal credit, a utility will then use "tools" from a "toolbox" to meet the required inactivation/removal. Some of the "tools" available and their potential inactivation/removal credit are:

- Combined filter effluent turbidity of < 0.15 NTU 95 percent of the time, 0.5-log
- Individual filter effluent turbidity of < 0.15 NTU 95 percent of the time, 0.5-log
- Ozone disinfection, 0.5- to 1.0-log
- River bank filtration, 1- to 2-log
- UV irradiation, greater than 3-log

Based on the tools available, LWS is investigating *Cryptosporidium* and *Giardia* removal credits for river bank filtration. Additional removal credits could reduce the ozone dose required for disinfection and reduce the need to use other "tools" for *Cryptosporidium* inactivation/removal.

5.1.3 Arsenic

Regulations have been finalized that set the arsenic MCL at 10 ppb. Based on historic sampling, the arsenic concentration varies between 6 and 7 ppb in the finished water, therefore, LWS should be able to meet the arsenic MCL. If water quality changes or the MCL is reduced, LWS will need to evaluate removal techniques, such as coagulation with ferric-salts or activated alumina.

5.1.4 Atrazine and Daughter Products

The current MCL for atrazine is 3 ppb, and to date, ozone has been effective for meeting the MCL. However, EPA is considering requirements to pool atrazine and its daughter products into a total MCL. LWS should start monitoring for daughter products to assess the need for further treatment in the future if they are included in the MCL. It is recommended that LWS continue to work with the agricultural community to reduce contaminants through watershed management, as it is the most cost effective method.

5.2 Ozone System Improvements

The existing ozonation system has been in operation since 1994 and uses air to generate ozone. Since the installation of the system, the design of ozone systems has changed, with ozone contactors having more cells with shorter contact time per cell to increase the efficiency. There has also been a drastic change in the ozone generation technology, as current systems operate on high purity oxygen and generate ozone at 10 to 14 percent by weight. Improvements to the ozone system to meet future production requirements have been divided into short-term and long-term improvements.

5.2.1 Short-term Improvements

During the summer months LWS currently is adding chlorine upstream of the ozone system to meet treatment requirements. This process is required because the ozone system cannot meet the rated capacity due to cooling water temperature, which exceed the design temperature. If the cooling water system is converted to a chilled water system or a lower temperature water source, the ozone generators should be able to return to the rated capacity during the summer months. Another improvement to the system is to divide the existing cell 1 with baffle walls to improve the flow characteristics through the basins. The baffle walls will potentially allow the ozone dose to be decreased because the short-circuiting through the contactor should decrease.

5.2.2 Long-term Improvements

Due to technology advances, the best option to meet future ozone capacity requirements is to convert to a liquid oxygen (LOX) based system, that includes three new oxygen based generators and conversion of one of the existing air based generators to oxygen. The new oxygen based generators should fit within the existing area for the air based generators, and will therefore not require additional building space. The initial conversion would occur when the ozone plant is expanded to 75 mgd. Three new generators would be provided and one of the old generators would be converted to oxygen service to provide backup capacity. The LOX system would be sized for future conditions, so when the plant is expanded to 100 mgd, only one additional generator would be required.

5.3 Water Treatment Plant Improvements

The recommended improvements at the water treatment plants are driven by the need for additional capacity or through changes in treatment regulations. The expansion costs are summarized in Table ES-5.

Table ES-5
Water Treatment Plants
Opinion of Probable Costs

Year	Description	Cost $
2003	Ozone Cooling Water Upgrades	310,000
2003	Relocate WTP Pre-chlorination Point	90,000
2004	Ozone Contact Basin Baffle Walls	260,000
2009	Ozone Expansion	3,700,000
2007-2011	25 mgd Water Treatment Plant Expansion(1)	13,000,000(2)
2020	25 mgd Water Treatment Plant Expansion(1)	13,000,000(2)
2020	Ozone Expansion	600,000
	Total	30,960,000
Reg.(3)	UV Disinfection	1,000,000-4,000,000
Reg.(3)	Arsenic Removal Modifications	18,000,000-23,000,000
	Total	19,000,000-27,000,000

(1) Expansion costs are based on process requirements to meet existing regulations.
(2) Does not include ozone equipment costs.
(3) Implementation will be driven by regulatory changes.

6. Distribution System

6.1 Existing Water Distribution System Facilities

Historically, the LWS service area has been divided into four service levels - Low, High, Belmont, and Southeast as previously shown on Figure ES-1. In 2001, the Cheney Booster District was created in the southeast portion of the service area to serve new development on high ground around 84th and Highway 2. Also in 2002, the Northwest Booster District was created near the NW 12th Street Reservoir, to serve a new development on high ground in that area.

6.2 Water Main Replacement Program

As part of the Facilities Master Plan, LWS requested an external review of the existing water main replacement program to develop an understanding regarding the adequacy of their program. The primary objective of a replacement program is to allocate main replacement funds commensurate with deterioration of the existing infrastructure occurring within the system. Table ES-6 provides a summary of water main breaks by pipe material and size from 1997 to 2001.

Table ES-6
Summary of Main Breaks by Pipe Material 1997 to 2001

Size inches	Material				
	Cast Iron	Ductile Iron	PVC	Asbestos	Total
4	58	2	0	0	60
6	246	16	1	10	273
7	1	0	0	0	1
8	21	2	0	2	25
10	3	0	0	1	4
12	8	9	0	0	17
16	1	3	0	0	4
20	1	0	0	0	1
Total	**339**	**32**	**1**	**13**	**385**

The number of breaks per year was evaluated based on the current funding level of the main replacement program which is $1.2 million per year. The results of the evaluation are summarized below:

- The average number of main breaks over the 1997 to 2001 period is 77, which translates into a main break rate of about seven per 100 miles per year. This level of main break activity is well below the "reasonable goal" stated in AWWARF's report *Distribution System Performance Evaluation* of 25 to 30 main breaks per 100 miles per year.

- Over the past 40 years, the number of breaks per year has increased at an average rate of about 2.5 breaks per year. If this trend continues, it is projected that the distribution system would experience about 168 breaks per year (15 breaks per 100 miles per year) by the year 2020, which is not excessive.

- Assuming a 100 year service life for water mains, one percent of the system should be replaced every year to prevent the system from deteriorating. This level of replacement translates to funding of $4.3 million per year.

- It is recommended that LWS develop a GIS database to more adequately monitor breaks within the distribution system. Review of the existing main break information and the existing replacement program indicate that an increase in the number of breaks and the associated replacement cost is inevitable due to aging of the mains. The necessary data required for more rigorous analysis are outlined within the report.

6.3 Transmission and Distribution Analyses

For the evaluation of the transmission and distribution system a computerized hydraulic model was developed within H_2OMAP using information from the existing GIS database system. The model was utilized to conduct hydraulic analyses which evaluate the transmission and distribution system, and are used to establish an improvement program to reinforce the existing system. Criteria used to develop the improvement program include increasing system reliability, simplifying system operations, more effectively utilizing system storage to meet peak demands, and maintaining pressures of 40 psi under maximum hour demand conditions.

6.4 Vulnerability Analysis (Lincoln Supply)

A vulnerability analysis considered the impacts to the distribution system upon total loss of the primary supply. In this situation, water would be supplied solely from the backup water supply. In addition, water stored in reservoirs could be used to help meet demands for a limited amount of time.

6.5 Water Quality and Extended Period Simulation Analyses

6.5.1 Historical Distribution System Water Quality

The LWS distribution system sampling program consists of conducting about 11 chlorine residual tests every working day at routine sampling points. LWS provided chlorine residual sampling data for the Lincoln distribution system, covering the period from January 2, 1997 through October 26, 2001. The data was reviewed for this study. The data consisted of a total of 14,115 test result records with fields for the collection date, sample site identification number, sample collection address, and residual chlorine in milligrams per liter (mg/l).

6.5.2 Water Age Analyses

The computer hydraulic model was configured to conduct extended period simulation (EPS) analyses. Using the EPS function, water age in the distribution system was modeled under existing minimum day and average day conditions. The results of the water age analyses were compared to the historical chlorine residual in the distribution system.

The analyses indicated that the water age in the Southeast Service Level is the oldest in the water distribution system. The water age analyses appear to correlate well to the historical chlorine residual measurements.

6.6 Recommended Water Distribution System Improvements

Recommended distribution system improvements are shown on Figure ES-4. The Phase I improvements are those that have been identified as higher priority as a result of their immediate need or as a result of known or currently anticipated development proposals. The Phase II improvements are those recommended to meet year 2010 demand conditions as evaluated for this study. The Phase III improvements are recommended to meet year 2025 demand conditions.

Table ES-7 Summary Costs for Phase I Improvements	
Description	Capital Cost ($)
Belmont System Pumping	200,000
Transfer Pumping	1,500,000
Low Service Level	600,000
Pumping Station to Belmont	1,400,000
Southeast Service Level Storage	7,900,000
Construct Phase I Main Improvements (28 projects)	26,600,000
Total Phase I Improvements	**$38,200,000**

Table ES-8 Summary Costs for Phase II Improvements	
Description	Capital Cost ($)
Construct Transmission Mains	31,500,000
Construct Phase II Distribution Main Improvements (39 projects)	21,000,000
Total Phase II Improvements	**$52,500,000**

Table ES-9 Summary Costs for Phase III Improvements		
Description	Year	Capital Cost ($)
Pump No. 1 (to High SL)	2012	1,000,000
Pump No. 5 (to High SL)	2012	1,000,000
Convert Pump No. 9 from High SL to Low SL	2012	1,200,000
Construct Elevated Tank (Cheney SL)	2012	4,300,000
Add Pump No. 8 (to Southeast SL)	2017	1,000,000
Add Pump No. 4 (to Belmont SL)	2018	200,000
Add Pumps No. 13 and 14 at WTP (335 TDH pumps)	2018	8,000,000
Construct Pumping Station (to Cheney SL)	2023	1,800,000
Construct Phase III Main Improvements (70 projects)		31,800,000
Total Phase III Improvements		**$50,300,000**